PATENT SPECIFICATION

(11) 1 540 403

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(21) Application No. 27007/76 (22) Filed 29 June 1976

(31) Convention Application No. 595 890 (32) Filed 14 July 1975 in

(33) United States of America (US)

(44) Complete Specification published 14 Feb. 1979

(51) INT. CL.² H01G 13/00 1/147

(52) Index at acceptance

H1M 1B2B7 1B2C11 1B2C2 1B2C9 1G12 1P14 1P1 1P2 DB

(19)

(54) METHOD FOR MAKING MULTI-LAYER CAPACITORS

(71) We, T.R.W. INC., a corporation organised and existing under the laws of the state of Ohio, of 10880 Wilshire Boulevard, Los Angeles, California 90024, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to a method of making multi-layer capacitors.

Multi-layer capacitors in general comprise alternate layers of a dielectric, such as a ceramic, and a metal conductor bonded together into a body. Alternate ones of the metal conductors are electrically connected together at one end of the body and the other of the conductors are electrically connected together at the other end of the body. Generally, the conductors are connected together by metal termination film coated on the ends of the body. A major problem in making these capacitors is in the manner of terminating the multi-layer capacitors so as to make good electrical contact to the conductors which extend to the ends of the body. It has been the practice to apply the termination to the ends of each body individually. However, this is not only time consuming and, therefore, expensive, but can also be difficult for very small size capacitors. Also, the terminations are generally of a noble metal, such as silver, which also adds to the cost of the capacitor.

Recently there has been developed a method of applying the termination wherein a plurality of the capacitor bodies are encapsulated in a plastics block with the capacitors arranged in spaced, parallel relation and with the ends of the capacitors being exposed at opposed surfaces of the block. The termination is applied to the exposed ends of the capacitor bodies. However, a problem with this method is in supporting the capacitors in order to encapsulate them in the block.

It is therefore an object of the present invention to provide a method of terminating a multi-layer capacitor.

According to the present invention there is provided a method of making a multi-layer capacitor comprising the steps of:

(a) forming a plurality of bodies of substantially final length and width with each body having alternate layers of a dielectric material and a conductive material with each conductive layer being sandwiched between a pair of dielectric layers and with some of said conductive layers extending to one end face of said body but being spaced from the opposite end face of the body, and the others of said conductive layers extending to the said opposite end face of the body but being spaced from the said one end face of the body;

(b) releasably securing said bodies to a thin support sheet with all of said bodies being supported by said support sheet in spaced, substantially parallel relation;

(c) encapsulating substantially the whole of said supported bodies in dissolvable material so as to form a block having opposite substantially flat surfaces at which the end faces of said bodies are exposed,

(d) coating each exposed end face of said bodies with a film of a conductive metal contacting the conductive layers of the body which extend to the end face of the body; and then

(e) separating the bodies from each other.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

FIGURE 1 is a longitudinal sectional view of one form of the multi-layer capacitor of the present invention,

FIGURES 2 and 3 are plan views of portions of the metalizd ceramic layers used to make the capacitor of the present invention,

FIGURE 4 is a sectional view showing the metalized ceramic layers laminated together,

FIGURE 5 is a perspective view of a capacitor body made from the laminate shown in FIGURE 4,

FIGURE 6 is a perspective view showing a plurality of the capacitor bodies mounted on a support sheet of the present invention,

FIGURE 7 is a perspective view showing the capacitor bodies encapsulated in a plastics block,

FIGURE 8 is a perspective view, partially broken away, of the plastics block of FIGURE 7 after being treated to expose the end portions of the capacitor bodies,

FIGURE 9 is a perspactive view, partially broken away, of the plastics block of FIGURE 8 with a termination film being coated on the capacitor bodies,

FIGURE 10 is a perspective view, partially broken away, of the plastics block of FIGURE 9 with a solder layer on the termination film,

FIGURE 11 is a plan view of a modification of the support sheet of the present invention,

FIGURE 12 is an edge plan view of another modification of the support sheet of the present invention.

Referring initially to FIGURE 1, a form of the multi-layer capacitor of the present invention is generally designated as 10. The capacitor 10 comprises a substantially right parallelepiped body 12 made up of alternate dielectric layers 14 and conductive layers 16 laminated together. The outer layers of the body 12 are both dielectric layers 14 so that each conductive layer 16 is sandwiched between two dielectric layers 14. The dielectric layers 14 may be of a material having the desired dielectric constant for the particular capacitor being made. Preferably, the dielectric layers 14 are of a ceramic material, such as the barium titanate ceramics. The conductive layers 16 may be of any conductive material. However, the conductive layers 16 are preferably of a relatively non-oxidizable metal which does not react with the material of the dielectric layers 14, such as silver, gold, platinum, palladium or mixtures or alloys thereof. A preferred means for applying the conductive layers 16 is by screen printing.

Alternate ones of the conductive layers 16 extend to one end face 12a of the body 12, but are spaced from the other end face 12b of the body 12, whereas the other conductive layers 16 extend to the other end face 12b of the body but are spaced from the one end face 12a. Although the body 12 is shown as having four conductive layers 16, it may include any number of the conductive layers depending on the desired capacitance of the capacitors 10. At the end faces 12a and 12b of the body 12, there are exposed respective conductive layers 16 which extend to the particular end of the body 12.

A separate termination film 18 is on each end face 12a and 12b of the body 12 and extends over a short portion of the outer surface 29 of the body 12 proximate to the end faces 12a and 12b. The termination films 18 adhere to the dielectric layers 14 and contact the conductive films 16 at the respective end of the body. Thus, each termination film 18 electrically connects in parallel a plurality of the conductive layers 16. The termination films 18 are of any electrically conductive metal, but are preferably of nickel. Each of the termination films 18 may be coated with a layer 20 of solder to improve their oxidation resistance.

To make the multi-layer capacitor 10 in accordance with the method of the present invention, the first step is to make a plurality of the multi-layer capacitor bodies 12. One method of achieving this is to form a plurality of green, unfired sheets 22 of ceramic particles mixed with a binder, such as polyvinyl chloride or polyvinyl acetate. Each of the sheets 22 is coated on one side with rectangular areas 24 of a conductive material with the areas 24 being arranged in a pattern of rows and columns. Some of the sheets 22a are coated with the conductive areas 24 in a pattern such as shown in FIGURE 2 wherein the areas in the end columns are one-half the width of the areas in the other columns. Some of the sheets 22b are coated with the conductive areas in a pattern such as shown in FIGURE 3 wherein all of the areas are of the same width. A plurality of the coated sheets 22a and 22b are then stacked on each other in alternating relation as shown in FIGURE 4. The sheets are arranged with the coated sides facing the same direction and an uncoated sheet 22 is placed over the conductive areas at the top of the stack. For example, in the stack of the sheets shown in FIGURE 4, the sheet 22b shown in FIGURE 3 is at the bottom of the stack followed by a sheet 22a, then another sheet 22b, then another sheet 22a and finally on top an uncoated sheet 22. Thus, each pattern of conductive areas is sandwiched between two dielectric sheets.

In the stacked array of the coated sheets, the rows of conductive areas are in directly overlapping, stacked arrangement. However, as shown in FIGURE 4, the columns of the conductive areas are off-set so that the space between each column of conductive areas of each sheet extends along the middle of the column of the conductive areas on the adjacent sheets. The stacked sheets are then laminated together by the

application of sufficient pressure to achieve adherence between the sheets. The laminated sheets are then divided into the individual capacitor bodies 12 by cutting along all of the spaces between the columns of the conductive areas as indicated by the dash lines 26 in FIGURE 4, and cutting along the space between the rows of the conductive areas. Where a cut is made along the overlapping spaces between the columns of the conductive areas of two of the sheets, the cut will go through the center of the conductive areas of the other two sheets. Thus, the conductive areas of the two sheets will be spaced slightly from the cut edge whereas the conductive areas of the other two sheets will extend directly to the cut edge. Thus, in each of the resultant capacitor bodies 12, each of the conductive areas will extend directly to an end edge of the body but will be spaced slightly from the other end edge with alternate conductive areas extending to opposite end edges of the bodies. The capacitor bodies 12 are then fired at a temperature high enough to sinter the ceramic particles of the sheets together to form a hard ceramic body having the conductors embedded therein.

Instead of making the laminated stacked array of sheets shown in FIGURE 4 from preformed sheets as described above, a similar structure can be made by a spray coated technique. For this technique a metal base plate is spray coated with a ceramic slurry. After the ceramic layer dries, a pattern of conductive areas is coated on the ceramic layer either by spraying through a mask or by silk screening. Additional layers of the ceramic material and the conductive material are similarly applied in sequence with the final layer being a ceramic layer. The resultant laminate is then removed from the metal plate and cut into the individual capacitor bodies 12 which are then fired.

A plurality of the fired capacitor bodies are then inserted through the holes in a thin support sheet 27 as shown in FIGURE 6. The support sheet 27 is of an inexpensive, disposable material, such as cardboard or plastic. The holes are preferably slightly smaller than the capacitor bodies 12 so that the capacitor bodies will fit tightly in the holes. The capacitor bodies 12 are positioned in the holes so that the end surfaces of all of the bodies at each side of the support sheet 27 are substantially coplanar.

The support sheet 27 with the capacitor bodies 12 inserted therethrough is then encapsulated in a block 28 of a plastics material with the plastics block 28 having opposite, substantially flat surfaces 30 which are substantially coplanar with the end surfaces of the capacitor bodies 12 and with the end surfaces of the capacitor bodies being exposed at the flat surfaces 30 of the block 28 as shown in FIGURE 7. This may be accomplished by using a suitable rectangular mold with opposite sides extending proximate to or in contact with the end surfaces of the capacitor bodies 12 received therein. The block 28 is of a material which is relatively inexpensive and which is controllably soluble in a solvent which does not attack the material of the capacitor bodies 12. Polyester resins have been found suitable for this purpose. However, epoxy, polyurethane, silicone and thermoplastic resins as well as such waxes as candle waxes can also be used.

The block 28 is then immersed in a suitable solvent for a period of time necessary to dissolve or soften the surface of the block 28. As previously stated, the solvent is one which will slowly dissolve the particular plastics being used but does not attack the material of the ceramic bodies 12. When the plastics is a polyester resin, methylene chloride has been found to be a satisfactory solvent. Chlorinated solvents can be used for epoxy and silicone resins, alcohols or ketones for polyurethane, and various hydrocarbon solvents for waxes. Whe the block 28 is removed from the solvent, it is washed with water to remove the softened layer of the block 28 and any of the solvent. This exposes a portion 19a of the outer 19 surfaces of each of the capacitor bodies 12 at each end of the capacitor bodies as shown in FIGURE 8. The amount of the outer surface 19a at the ends 12a and 12b of the capacitor bodies 12 which are exposed depends on the length of time that the block 28 is immersed in the solvent. Using methylene chloride as a solvent for a polyester resin, and leaving the block 28 in the solvent for approximately ten minutes will dissolve a sufficient amount of the plastics to expose about .02 inch of the outer surface 19a of the capacitor bodies 12 at each end of the bodies.

The exposed ends of the capacitor bodies 12 are then immersed in a suitable etchant for the particular dielectric material providing a roughened or pitted surface for improving the adherence of the nickel terminations 18 to the end surfaces of the capacitor bodies 12. When the dielectric material is a barium titanate ceramic, the etchant may be hydrofluoric acid, fluoboric acid or a mixture of organic fluorides in hydrofluoric acid. Also, when the dielectric material is a barium titanate, a second etch may be required to ensure removal of the barium fluorides formed during the initial etch.

As shown in FIGURE 9, a termination film 18 of an electrically conductive metal, such as nickel or copper, is then simultaniously coated on the exposed surface of each of the capacitor bodies 12. The termination films 18 are applied by the well known pro-

cess of electroless plating, such as described in United States Patents No. 3,075,855 to M. C. Agens, issued January 29, 1963, entitled "Copper Plating Process and Solutions," No. 3,095,309 to R. J. Zellisky et al, issued June 25, 1963, entitled "Electroless Copper Plating," and No. 2,968,578 to J. M. Mochal, issued January 17, 1961, entitled "Chemical Nickel Plating on Ceramic Material." It is well known that electroless plating first requires that the object to be plated be treated with a sensitizer prior to being subjected to the plating composition. To apply the termination films 18 to the exposed surfaces of the capacitor bodies 12, the entire block 28 is immersed in the sensitizing material so that the surfaces of the block 28 as well as the exposed surfaces of the capacitor bodies 12 are sensitized. The block 28 is then again immersed in the solvent for the material of the block to dissolve or soften the surfaces of the block 28. This removes the sensitized surfaces of the block 28 leaving only the exposed surfaces of the capacitor bodies 12 being sensitized. Thus, when the entire block 28 is subjected to the plating material, the metal will only plate on the sensitized exposed surfaces of the capacitor bodies 12 including the extending ends of the conducting layers 16 and the dielectric layers 14 and on the surfaces of the ends 12a, 12b to form the termination films 18.

The end surfaces of the block 28 from which the capacitor bodies 12 project may then be immersed in a bath of molten solder. Since the solder will only adhere to a metal surface, only the termination films 18 become coated with the solder to provide the solder layers 20 as shown in FIGURE 10. The block 28 is then again immersed in the solvent bath and left in the solvent until all of the plastic is dissolved so as to separate the individual capacitors 10 in the block 28. After the plastic is completely dissolved, the individual capacitors 10 are removed from the solvent and washed to remove the solvent.

Referring to FIGURE 11, a modification of the support sheet is generally designated as 32. The support sheet 32, like the support sheet 27, is of an inexpensive, disposable material, such as cardboard or plastic. The support sheet 32 has a plurality of circular holes 34 therethrough. The capacitor bodies 12 are rectangular in transverse cross-section with one cross-sectional dimension being larger than the other cross-sectional dimension. The holes 34 are of a diameter slightly smaller than the larger cross-sectional dimension of the bodies 12. Thus, when the bodies 12 are inserted through the holes 31, the bodies will be held firmly on the support sheet.

Referring to FIGURE 12, there is shown another modification of the support which is particularly suitable for very short bodies. For example, for making capacitors having bodies which are of a length of 1/16 inch or less, the support sheets having holes into which the bodies are inserted would not be completely acceptable. The support sheets are generally about 1/32 inch in thickness so that the bodies would not project enough beyond the support sheet to permit encapsulation with the plastic material to form the block. This modification of the support includes two sheets 36a and 36b, each of an inexpensive, disposable material. Each of the sheets 36a and 36b has a layer 38a and 38b respectively of an adhesive on a surface of the sheet. The sheets 36a and 36b are arranged in spaced, parallel relation with the adhesive layers 38a and 38b facing each other. The bodies 12 are mounted in spaced, parallel relation between the sheets 36a and 36b with the ends of the bodies contacting and being adhered to the adhesive layers 38a and 38b.

To mount the bodies 12 on the support, one of the sheets 36a or 36b is placed on a horizontal support with the adhesive layer 38a or 38b facing upwardly. The bodies are then placed on the sheet with an end of each body engaging the adhesive layer. The bodies will all be mounted in a vertical upright position on the one sheet. The other sheet with the adhesive layer facing downwardly is then placed over and in contact with the upright ends of the bodies. The support can then be placed in a mold and the space between the sheets is filled with the plastic material to encapsulate the bodies in the block. When the block is formed, the sheets 36a and 36b are removed to expose the ends of the bodies. By filling the space between the sheets with the plastic material, when the sheets are removed, the ends of the bodies will be substantially flush with the surfaces of the plastic block. The process of terminating the bodies can then be completed in the manner previously described.

The method of the present invention for making multi-layer capacitors on a mass production basis has the following advantages:

(1) Because of the small size of the capacitor bodies 12, it is much easier to handle the plastics block 28 which contains a plurality of the capacitor bodies, during the application of the termination films and solder layers than it is to handle the individual capacitor bodies. Although the plastics block is shown as containing only a few of the capacitor bodies 12, it can contain as many as 100 or more.

(2) The capacitor supporting sheets also facilitate the automation of the method for making the capacitors while the adhesive

support sheet also has the advantage of removing the requirement for aligning the capacitor bodies for insertion through the openings of the apertured support sheet.

(3) The adhesive support sheet also can be used for positioning extremely short capacitor bodies by engaging their ends and allowing the encapsulating material to completely surround the bodies intermediate their ends.

(4) It is desirable to have the termination films 18 extend around a portion of the outer surfaces of the capacitor bodies to permit ease of mounting the capacitors in a circuit. The method of the present invention provides for ease of applying the termination films 18 to the outer surfaces of the capacitor bodies with control of the extent of the outer surface covered by the termination films.

(5) By the use of the plastics blocks, a plurality of the capacitor bodies are simultaneously subjected to each step of the method of the present invention so that a desired number of the capacitors can be manufactured quicker than if the capacitor bodies were individually subjected to the various steps.

(6) Since a plurality of the capacitor bodies are simultaneously subjected to each step of the termination method of the present invention, the cost of manufacture per capacitor is considerably less than if the capacitor bodies were individually subjected to the various steps.

(7) The method of the present invention permits the use of an inexpensive process for the application of the termination films so as to reduce the cost of the capacitor.

Thus, the method of the present invention provides for the mass production of the multi-layer capacitors 10 with greater ease of handling the capacitors, with greater speed and at a lower cost per capacitor.

WHAT WE CLAIM IS:—

1. A method of making a multi-layer capacitor comprisi,g the steps of:

(a) forming a plurality of bodies of substantially final length and width with each body having alternate layers of a dielectric material and a conductive material with each conductive layer being sandwiched between a pair of dielectric layers and with some of said conductive layers extending to one end face of said body but being spaced from the opposite end face of the body, and the others of said conductive layers extending to the said opposite end face of the body but being spaced from the said one end face of the body;

(b) releasably securing said bodies to a thin support sheet with all of said bodies being supported by said support sheet in spaced, substantially parallel relation;

(c) encapsulating substantially the whole of said supported bodies in dissolvable material so as to form a block having opposite substantially flat surfaces at which the end faces of said bodies are exposed;

(d) coating each exposed end face, of said bodies with a film of a conductive metal contacting the conductive layers of the body which extend to the end face of the body; and then

(e) separating the bodies from each other.

2. A method in accordance with Claim 1 in which prior to coating the end faces of the bodies with metal film, there is included the step of etching away some of the dielectric material at each end face of each body to expose some of the conductive layers and to roughen the surface to increase adhesion.

3. A method in accordance with Claim 1 or Claim 2 in which the bodies are encapsulated so that the end faces of the bodies are substantially flush with the flat surfaces of the block, a portion of the surfaces of the block is removed so that the end faces of the bodies project beyond the block and the metal films are coated on the surface of the entire projectimg end portions of the bodies.

4. A method in accordance with any preceding Claim, in which the metal film is applied by electroless plating.

5. The method in accordance with any preceding Claim, in which the metal films are of nickel.

6. The method in accordance with any preceding Claim, in which prior to separating the bodies from the block the metal films are coated with a layer of solder.

7. The method in accordance with any preceding Claim, in which the dissolvable material is a plastics and the block is dissolvable by immersing the block in a solvent for the plastics.

8. A method in accordance with any preceding Claim, in which the support sheet has a plurality of spaced holes therethrough and each of the bodies extends through and is secured in a separate one of said holes.

9. A method in accordance with Claim 8, in which the holes are smaller than the cross-sectional dimension of the bodies so that the bodies fit tightly within the holes.

10. A method in accordance with Claim 9 in which each of the bodies is rectangular in transverse cross-section with one cross-sectional dimension being greater than the other and each of the holes being circular and of a diameter slightly smaller than the largest cross-sectional dimension of the bodies.

11. A method in accordance with any one of claims 1-7 in which the support sheet has a layer of adhesive on one surface and the bodies are secured to the support sheet with one end face of each of the bodies contacting and adhered to the adhesive layer.

12. A method in accordance with Claim 11 including a second support sheet having a layer of adhesive on one surface extending across the other ends of the bodies with the other end faces of the bodies contacting and adhered to the adhesive layer on the second support sheet.

13. A method in accordance with Claim 12, in which the bodies are encapsulated in the block by filling the space between the support sheets with the dissolvable material.

14. A method in accordance with Claim 13 in which after the bodies are encapsulated in the block, the support sheets are removed to expose the end faces of the bodies.

15. A method of making a multi-layer capacitor substantially as hereinbefore described with reference to the accompanying drawings.

16. Apparatus for carrying out the method of claim 15 and substantially as hereinbefore described wuth reference to the accompanying drawings.

FITZPATRICKS,
(Chartered Patent Agents),
14/18 Cadogan Street,
Glasgow, G2 6QW.
—and—
Warwick House,
Warwick Court,
London, WC1R 5DJ.

Printed for Her Majesty's Stationery Office by The Tweeddale Press Ltd., Berwick-upon-Tweed, 1979. Published at the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

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3 SHEETS

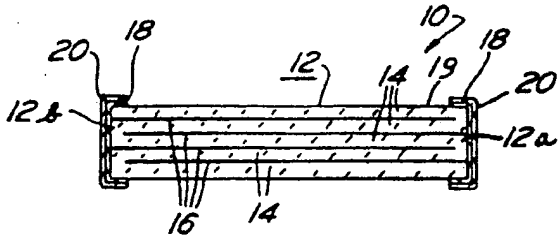


FIG. 1

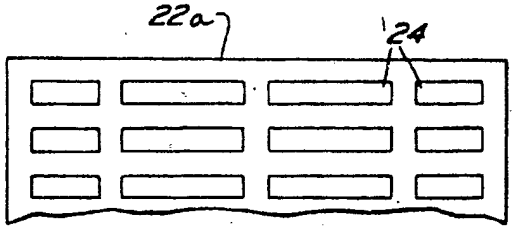


FIG. 2

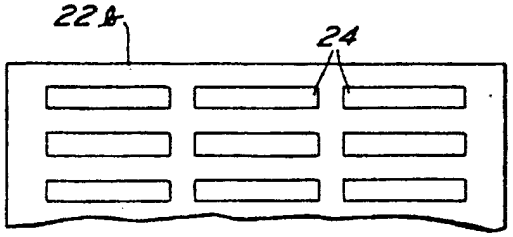


FIG. 3

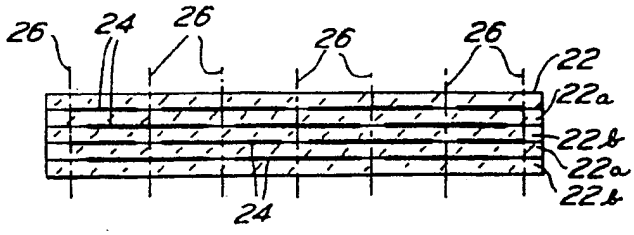


FIG. 4

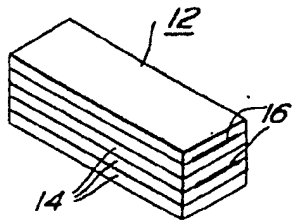


FIG. 5

1540 403 COMPLETE SPECIFICATION
3 SHEETS This drawing is a reproduction of the Original on a reduced scale.
SHEET 2

FIG.6

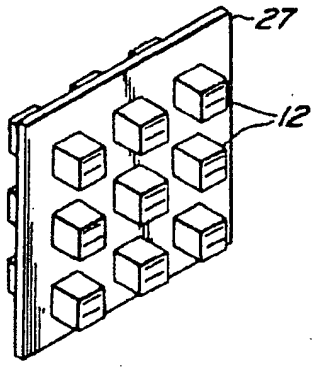
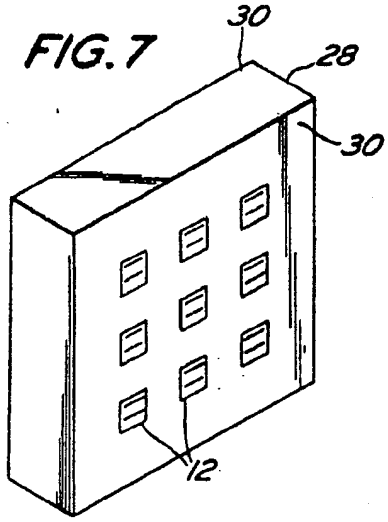


FIG.7



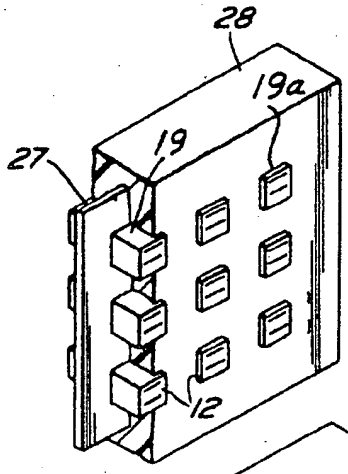


FIG.8

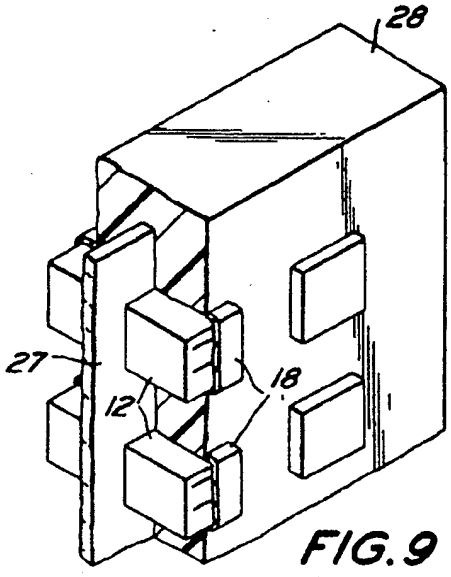


FIG.9

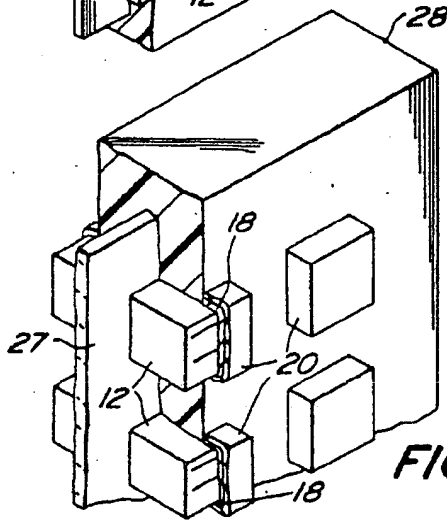


FIG.10

1 540 403 COMPLETE SPECIFICATION
3 SHEETS This drawing is a reproduction of the Original on a reduced scale.
SHEET 3

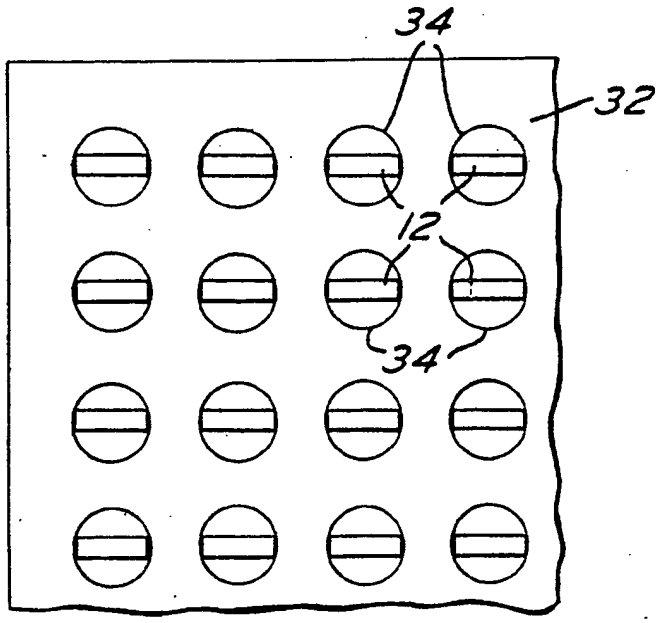


FIG. 11

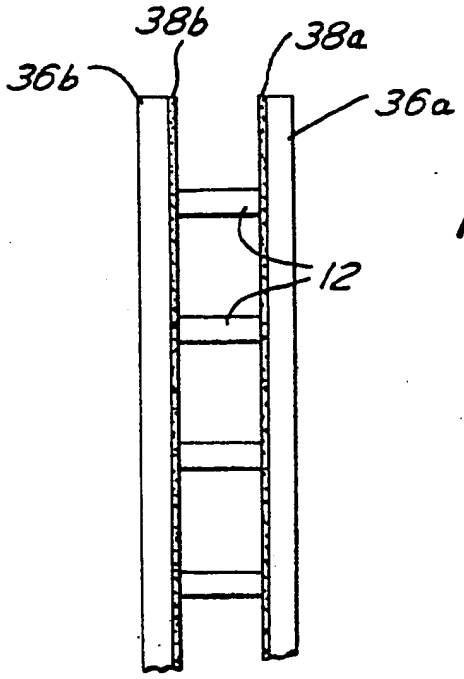


FIG. 12